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# ROLL-RATE STABILIZATION OF A MISSILE CONFIGURATION WITH WRAP-AROUND FINS IN INCOMPRESSIBLE FLOW

by

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This report contains the results of a subsonic wind tunnel test conducted to study the steady-state roll-rate characteristics of various wrap-around fin (WAF) missile configurations at angles of attack from 0 to 90°. The tests show that fin slots combined with wing tip fences and roll tabs eliminate the excessive roll-rate characteristics exhibited by WAF configurations at all angles of attack.

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## FOREWORD

The results of a study to eliminate the excessive roll rates at high angles of attack exhibited by missile configurations with wrap-around fin stabilizers are presented. The purpose of this study was to experimentally determine a method of roll-rate stabilization for this type of configuration to be used as an air-launched weapon.

This work was performed under the Inde Exploratory Development Program sponsored by the Director of Naval Labor.

This report was reviewed by H. P. Caster, Head, Exterior Ballistics Division.

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## INTRODUCTION

This work was undertaken as an initial phase of a research program to determine the potential of wrap-around fins (WAFs) as stabilizers for air-launched weapons. As a result of a previous investigation concerned with rocket flight dynamics,[1] it appeared that WAF configurations of proper design may avoid roll resonance and roll-yaw coupling, thus alleviating two problems plaguing current general-purpose bombs. However, a problem that is characteristic of WAF missile configurations is high roll rate at high angles of attack. The elimination of high roll rates is an important factor in controlling Magnus instability of air-launched weapons, particularly bombs.[2-4]

The purpose of this study was to determine if a fin modification could be found for WAF configurations that would provide roll-rate stabilization at all angles of attack.

## WIND TUNNEL TESTS

Free-rolling tests were conducted in the 28- by 40-in. subsonic wind tunnel located at Edgewood Arsenal.[5] The test specimen consisted of a free-rolling model with an ogival nose and a cylindrical afterbody, sting-mounted on ball bearings. The model was designed so that various fin configurations could be easily interchanged. A schematic of the basic configuration with fins extended (open) is presented i Figure 1. Steady-state roll rates were measured with a magnetic tachometer for angles of attack from 0 to 90°.

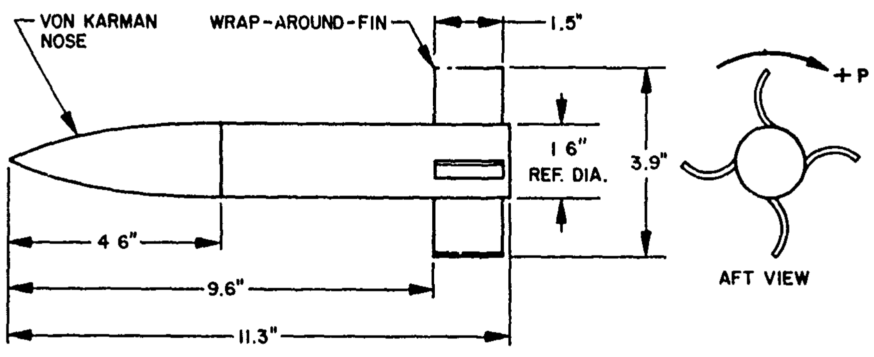


**Figure 1. Schematic of Wind Tunnel Model (Basic Configuration)**

## DISCUSSION OF RESULTS

The basic WAF configuration was tested, and a plot of the reduced frequency (Pd/2V) versus the model angle of attack ($\alpha$) is shown in Figure 2.

where

$P$ = steady-state roll rate, rad/sec
$d$ = reference diameter, 0.133 ft.
$V$ = velocity of free stream, ft/sec
$\alpha$ = total angle of attack,°

This configuration exhibited large negative steady-state roll rates at high angles of attack and a small positive, steady-state roll rate at zero angle of attack. The bar indicates a region of roll lock-in, e.g., where the motion, if stopped, will remain stopped.

A straight fin configuration with the same planform as the basic WAF configuration was also tested (see Figure 2). As expected, the configuration exhibited roll speed-up in both the positive and negative directions.[2] The unsymmetrical character of the roll rates exhibited by this configuration is probably due to strut interference. Interference is inferred since models with longer sting-to-strut distances exhibit more-symmetrical roll characteristics.

It had previously been shown that fin slots eliminated roll speed-up of straight finned missiles.[2,3] Consequently, fin slots were tested on the basic WAF configuration in the hope that the roll rates at high angles of attack would be reduced. The fin slot, centrally located, had an area of about 30 percent of the total fin area. The slot reduced roll rates at high angles of attack approximately 50 percent. Data for the slotted wraparound fin are presented in Figure 2.

At this point, it was obvious that an additional modification to the fin was required in order to provide roll-rate stabilization.

Since WAF configurations are not symmetrical in crossflow (see Figure 3), it was expected that a part of the high-angle-of-attack roll rate might be produced by differential drag. Consequently, fin fences might tend to equalize the drag differential between retreating and advancing fins. Figure 4 shows the effects of fin fences on the basic WAF configuration without slots. With fences at the fin tips, the roll rate is reversed except at very high angles of attack where the configuration can roll in either direction.

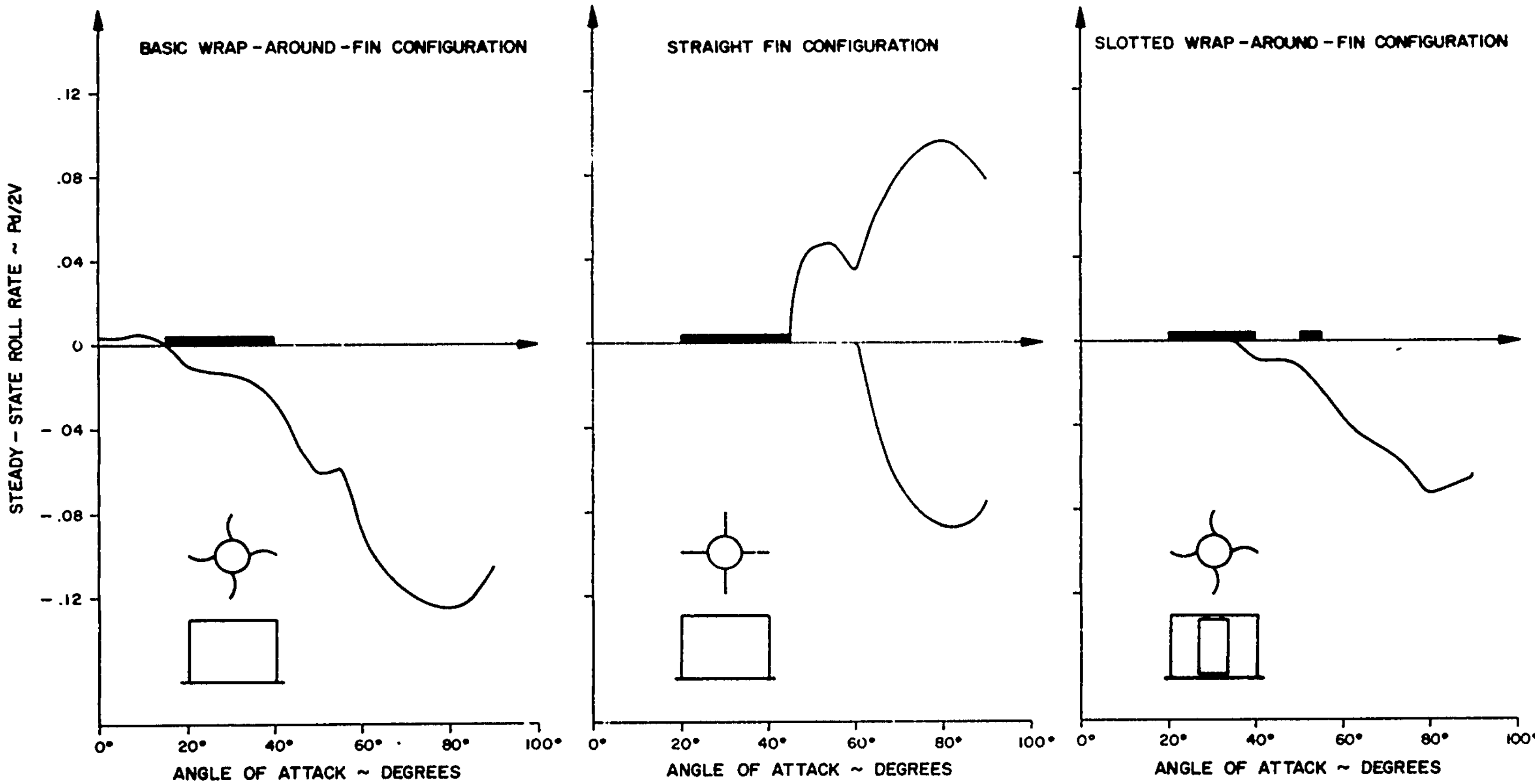


Figure 2. Steady-State Roll Rate vs Angle of Attack

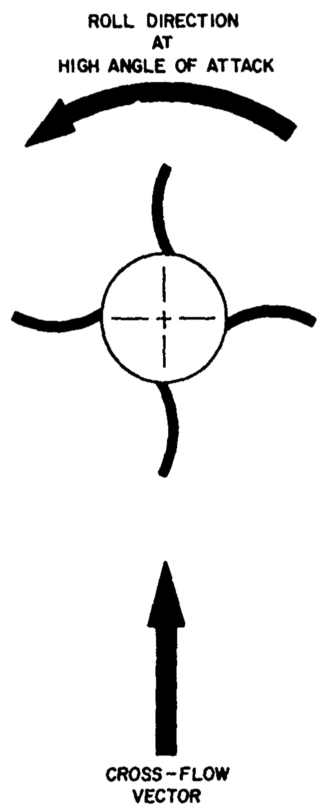


**Figure 3. Wrap-Around Fins in Crossflow**

An inboard movement of the fence (Figure 4) gives the WAF configuration the characteristics of a straight-fin configuration; e.g., the missile rolls equally well in both directions at high angles of attack.

Using a combination of slots and fences, the WAF configuration was then roll-rate-stabilized, as shown in Figure 5. The addition of a roll tab provided the required diiving torque. The dimensions of the final roll-stabilized configuration using slots, fences, and roll tabs are given in Figure 6. It should be noteJ that further refinement of the slot geometry and fence location was not attempted.

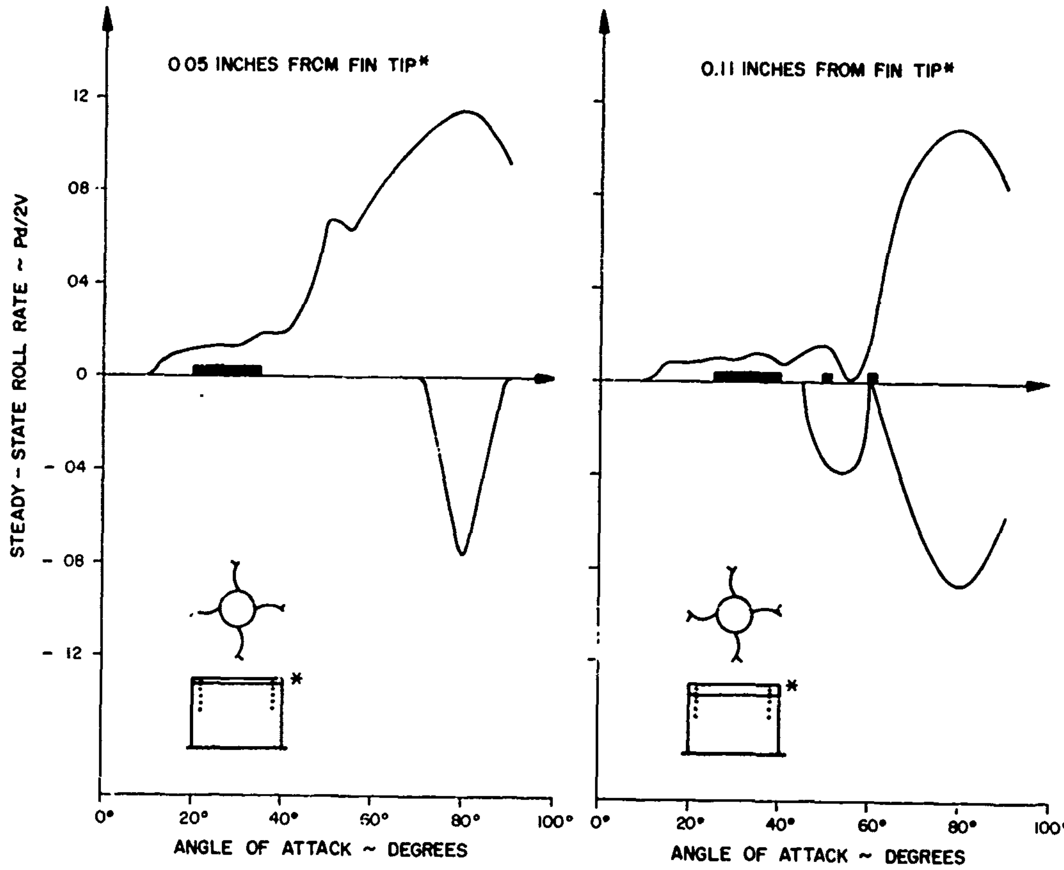


**Figure 4. Steady-State Roll Rate vs Angle of Attack for Wrap-Around Fin Configuration With Outboard Fences**

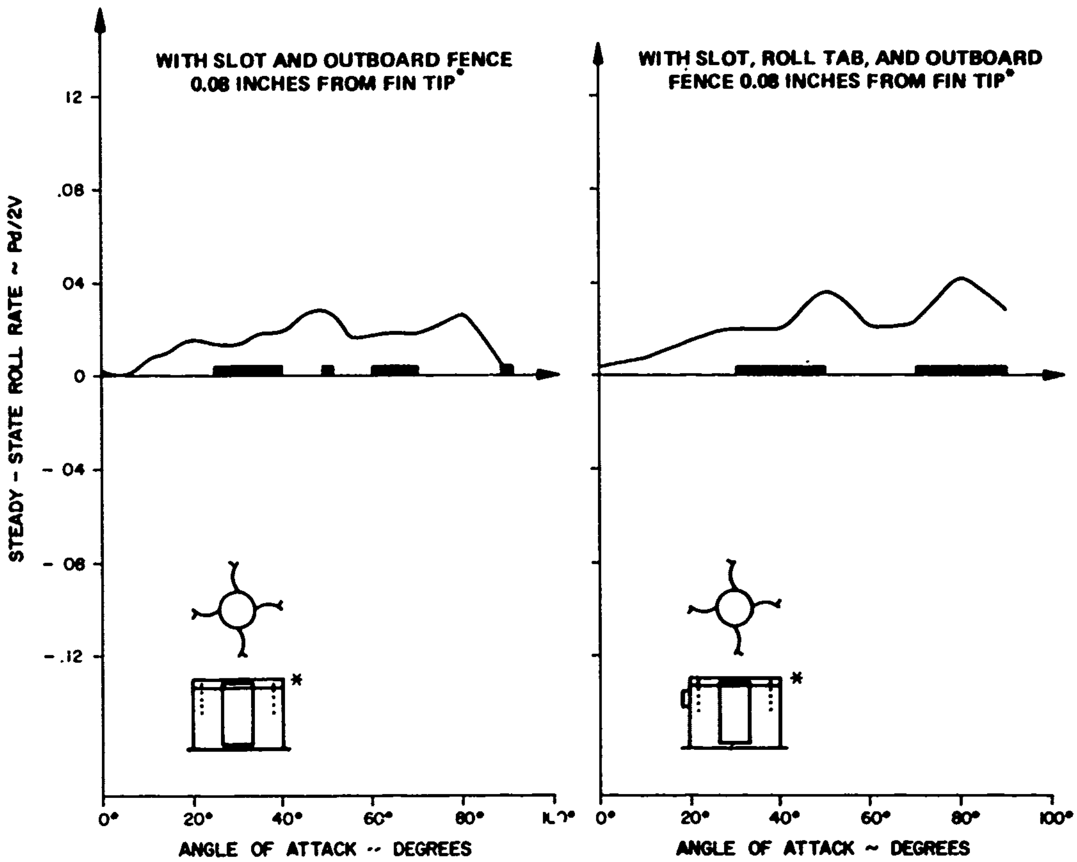


**Figure 5. Steady-State Roll Rate vs Angle of Attack for Wrap-Around Fin Configuration**

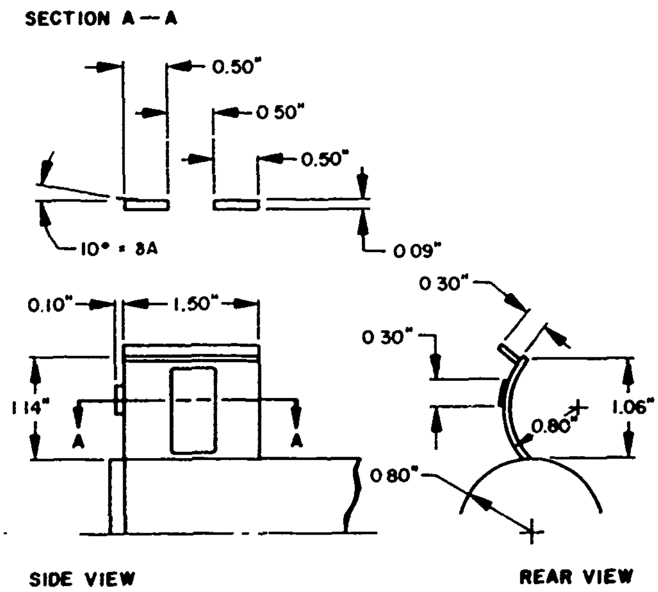


**Figure 6. Roll Stabilized Wrap-Around Fin Configuration With Slot, 10° Roll Tab, and Outboard Fence 0.08 In. From Fin Tip**

## CONCLUSIONS

The following conclusions are made based on the results of this study:

1. In incompressible flow, a missile configuration with wrap-around fins can be roll-rate-stabilized using fences and slots.
2. Roll rates of the basic WAF configuration at high angles of attack are probably due to vortices shed from the fins and the differential drag of the fins in crossflow.

Surprisingly, the fence position can cause the basic WAF configuration to behave like its straight fin counterpart, probably by equalizing the drag in crossflow. The slots eliminate the roll rates caused by vortex shedding on the wrap-around fins. Thus, the combination of fences and slots eliminates the large roll rates exhibited by WAF missile configurations at high angles of attack.

## COMMENT

The method of roll-rate stabilization presented in this report for wrap-around-fin configurations is relatively simple and practical. Consequently, additional high-speed tests are strongly recommended.

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